The Use of Silicates for Corrosion Control in Building Drinking Water Systems

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Objectives

- Provide an introduction to silicate chemistry
- Discuss the use of silicates for corrosion control in DW systems
- Present pilot and field study data where silicates were used to control lead, copper and/or iron release

Soluble Silicates

Chemistry

- Produced by mixing silica sand and sodium carbonate at 1100 to 1200°C
- Silicates are defined by the wt. ratio of SiO_2:Na_2O
  - Ratio of 3.22 is typical
  - Lower ratios may also be used (more basic)
- Concentrated solutions contain a mixture of polymeric and monomeric species
- Monomeric species dominate in dilute solutions (i.e., $Si(OH)_4$ and $HSiO_3^-$)

Silicates for Corrosion Control

- Zinc in hot water systems
  - Negatively charged silica species adsorbed to zinc hydroxide
  - Particle enmeshment
  - Need for existing corrosion deposit
- Aluminum
- Lead and Copper
  - Protective scale??
  - pH benefit

Silicates for Corrosion Control
Continued

- 24 mg SiO_2/L start-up dose (3.22 SiO_2/Na_2O)
- Incremental decrease dose after 30 to 60 days
- Maintenance dose of 8 to 12 mg SiO_2/L

The Use of Sodium Silicates to Prevent Red Water (Iron Precipitation)

- Added at point of (or shortly after) oxidant addition
- Adsorption/dispersion mechanism
- 12 mg SiO_2/L/2 mg Fe/L
- Cations such as calcium can interfere

Case Study #1: New Building
The Problem

- High and sporadic lead and copper
- Excessive use of lead:tin solder
- Brass fixtures
- New building, unused plumbing

Case Study #1: A New Building
Treatment Alternatives

- Remove lead-based solder joints
- Install point-of-use devices
- Use the system (flushing)
- Install chemical treatment (pH adj., phosphate inhibitors, silicate)

BUILDING STRUCTURE

- 2 sections
  - "animal" section
  - "laboratory" section
- Four levels (ground, 1st, 2nd, and 3rd floors)
- Each floor consisted of 2 wings
- Each wing consisted of 9 rooms
- Each room had at least 1 faucet and sink
- A large utility chase ran between wings
- Water lines supplying wings could be isolated

SOURCE WATER QUALITY

ANALYTE	YEARLY AVE.
Alkalinity	31 mg/L
pH	7.7 units
Calcium	18.3 mg/L
Magnesium	4.0 mg/L
Sodium	6.5 mg/L
Chloride	19.3 mg/L
Sulfate	12.5 mg/L
Silica	6.4 mg/L

CHEMICAL TREATMENT

- *"Generic" orthophosphate*
  - contains Na and K
  - dosage= 3.0 mg PO_4/L
- *Zinc orthophosphate*
  - dosage= 3.0 mg PO_4/L (Zn= 1.25 mg/L)
- ***Sodium silicate***
  - **"start-up" dosage= 24-30 mg SiO_2/L**
  - **"maintenance" dosage= 16 mg SiO_2/L**

SAMPLING PROCEDURE

Monday-Friday:

- *Water flow*
  - Faucets open 2 hours/day
  - Faucets open 4 times a day; 1/2 hr on/1 1/2 hr off
- *Sampling*
  - Tues. and Fri. samples are taken for metal analysis
  - Tues. samples were taken for general water quality
  - 12 hour stand time
  - pH was measured in the field

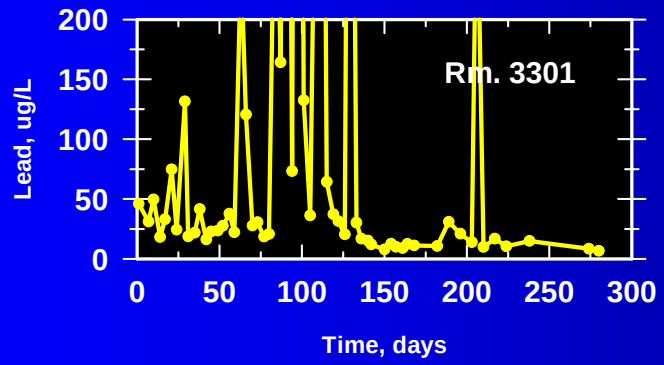
Building Configuration

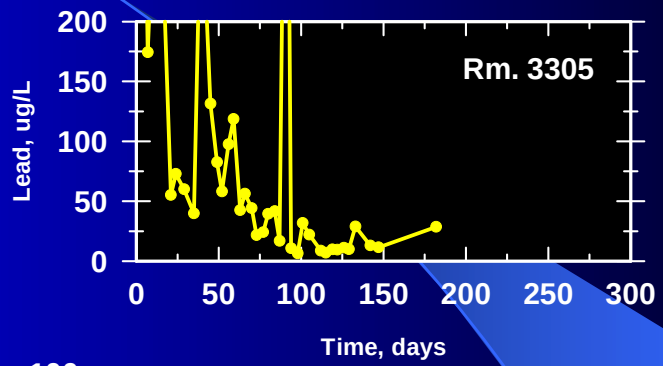
Sodium Silicate Feed System

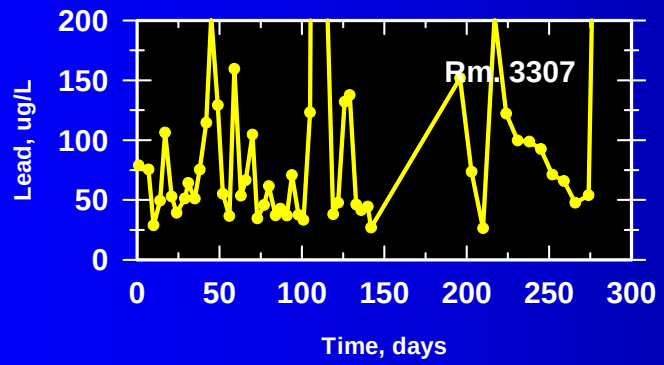
WATER QUALITY CHANGES

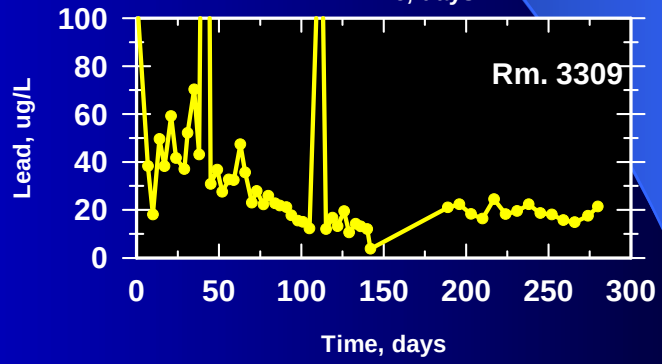
- *Sodium silicate*
  - » SiO_2= 32.0/16.3 mg/L
  - » pH= 9.5/9.0 (increase 1.8/1.3 units)
  - » Na=10.2 mg/L (increase 3.7 mg/L)

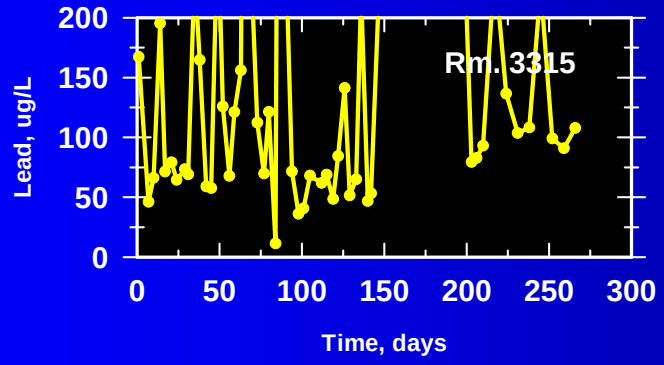
Lead- Control

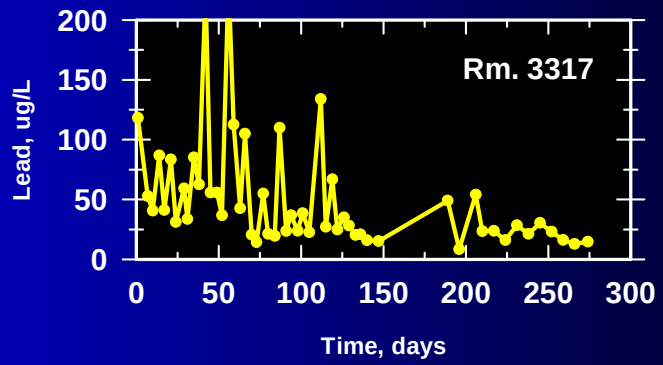




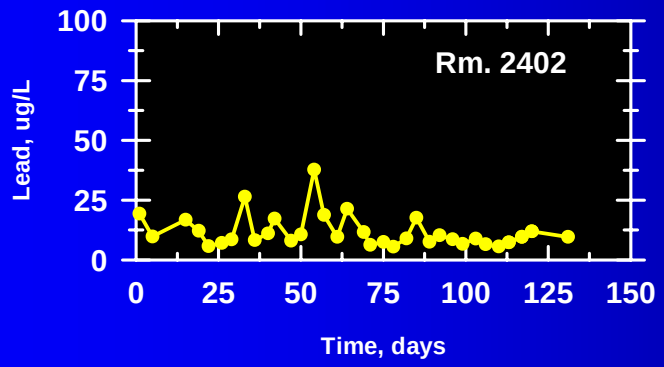


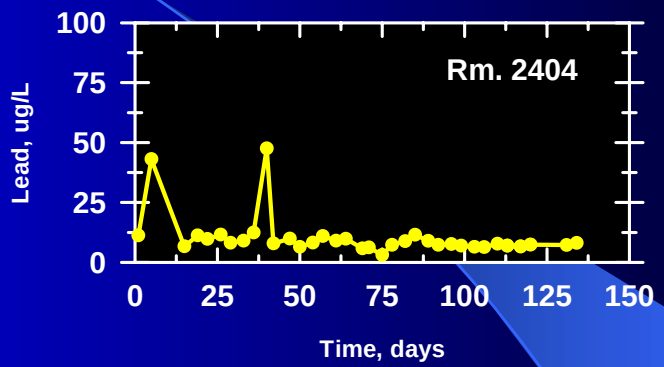


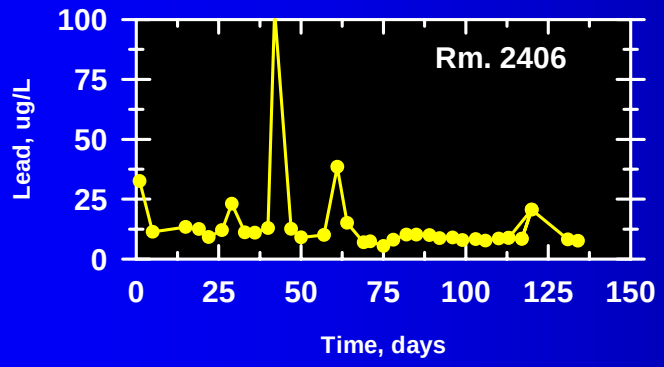


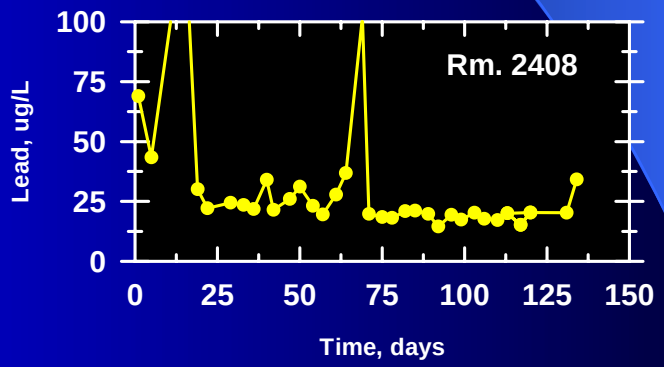


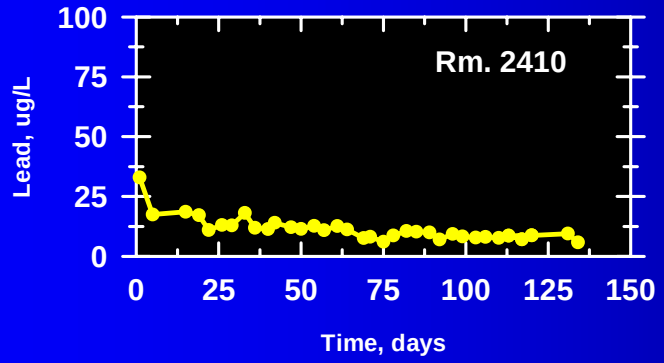
Lead- Silicate Treatment

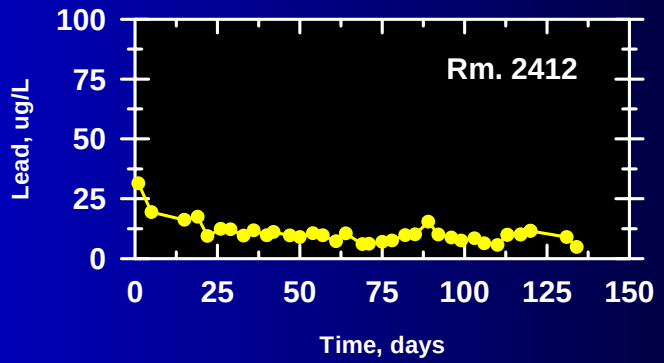




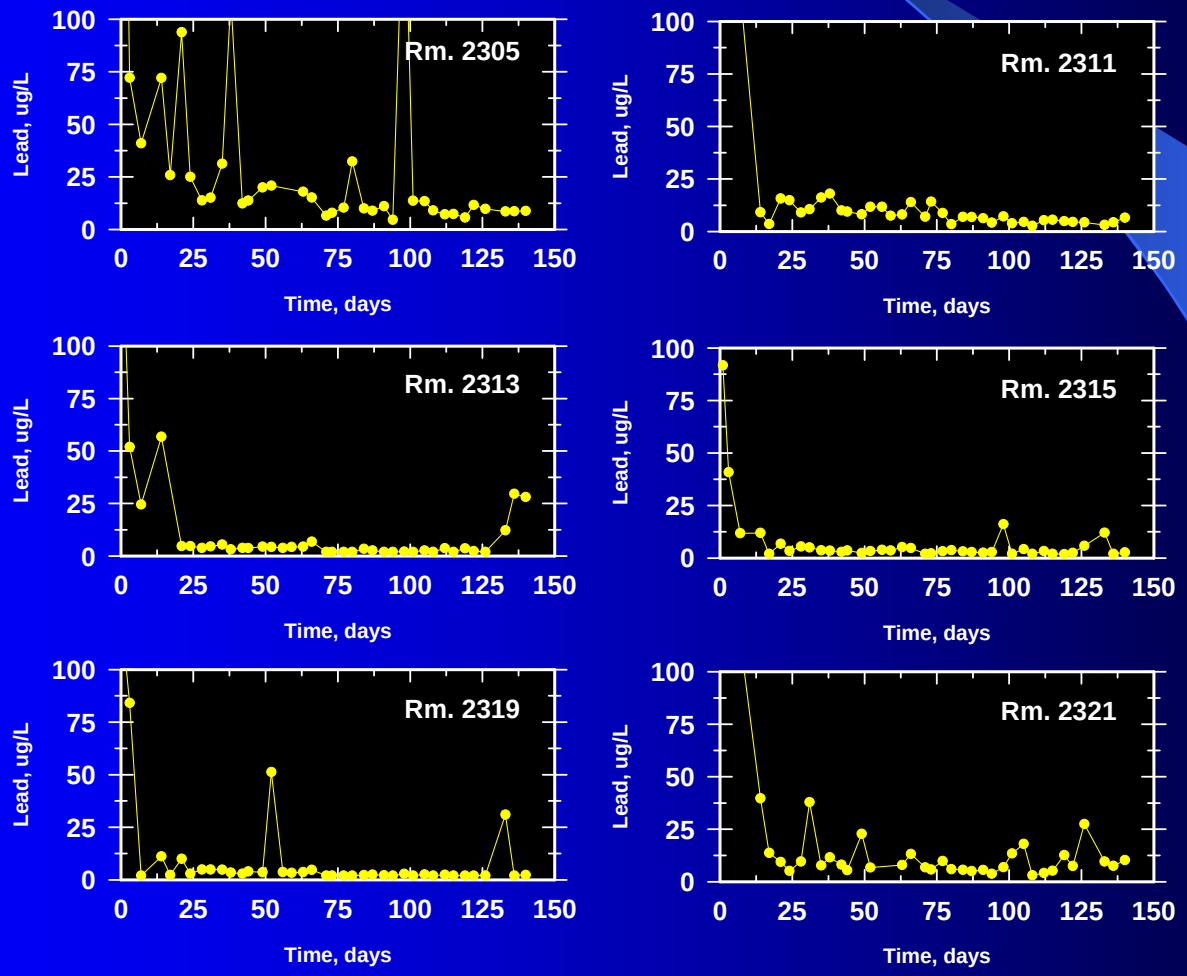




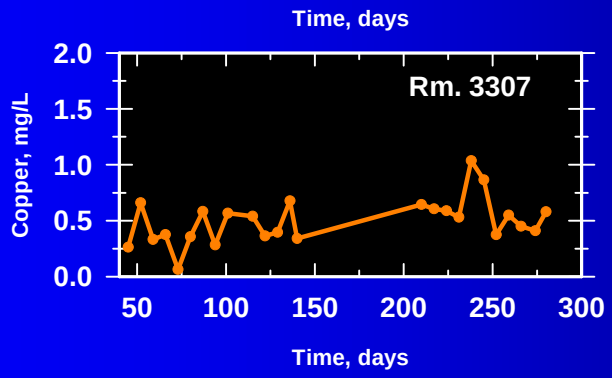


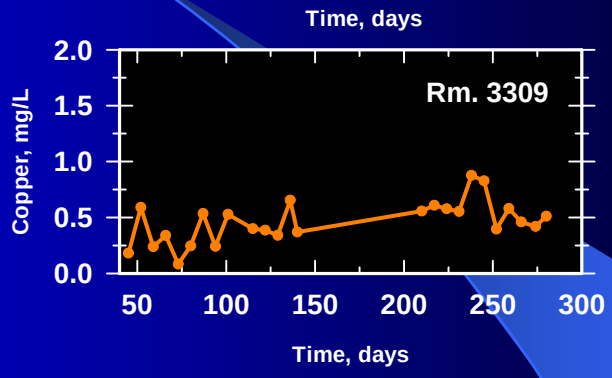


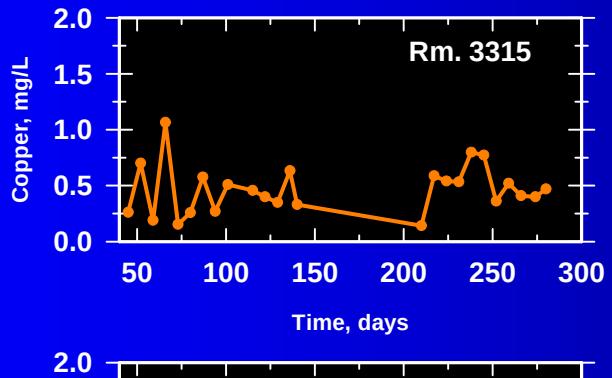
Lead- Calcium Orthophosphate

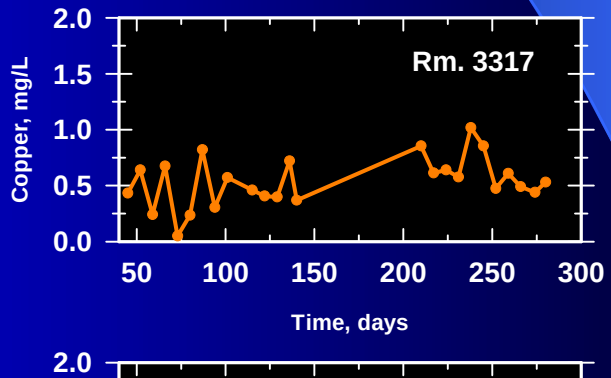


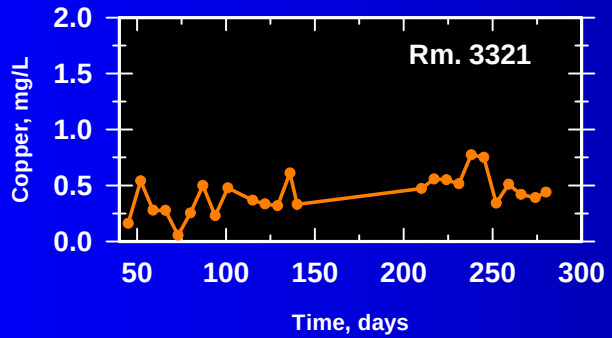
Copper- Control

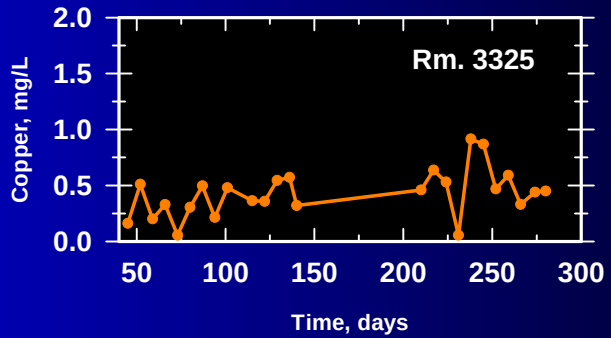




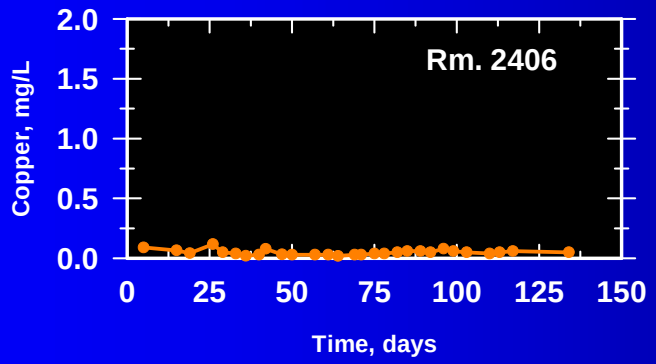


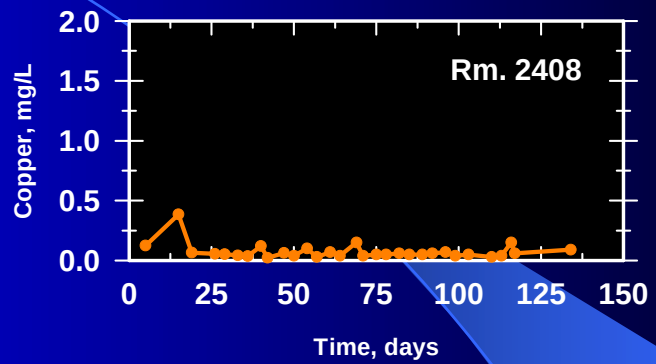


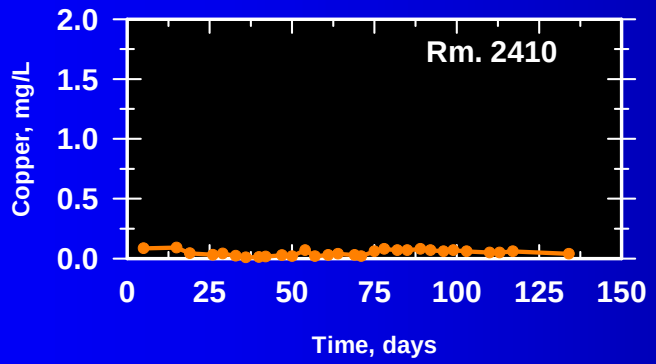


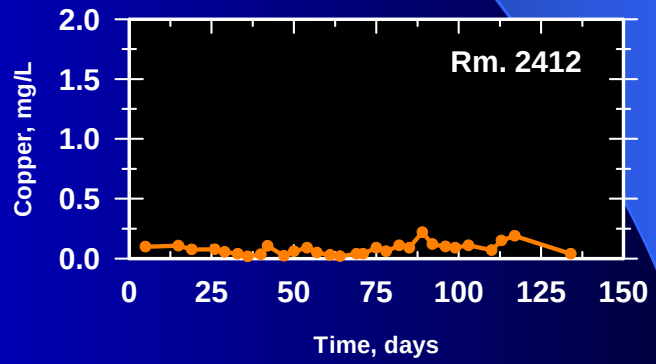


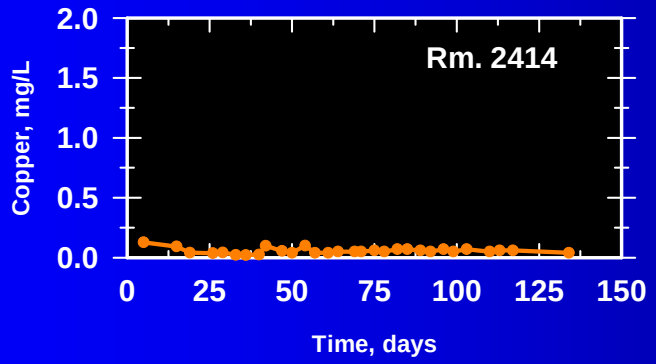
Copper- Silicate Treatment

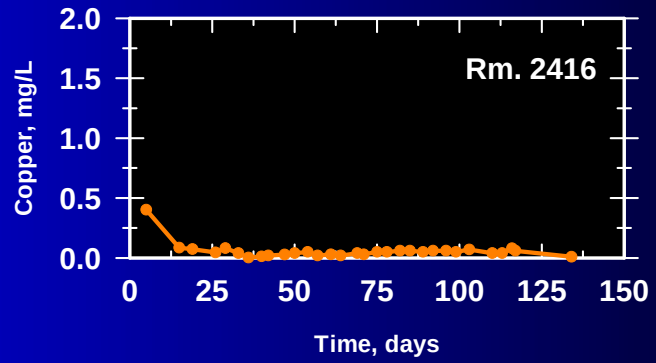












Case Study #2: Small Utility with a Lead and Copper, and Red Water Problem

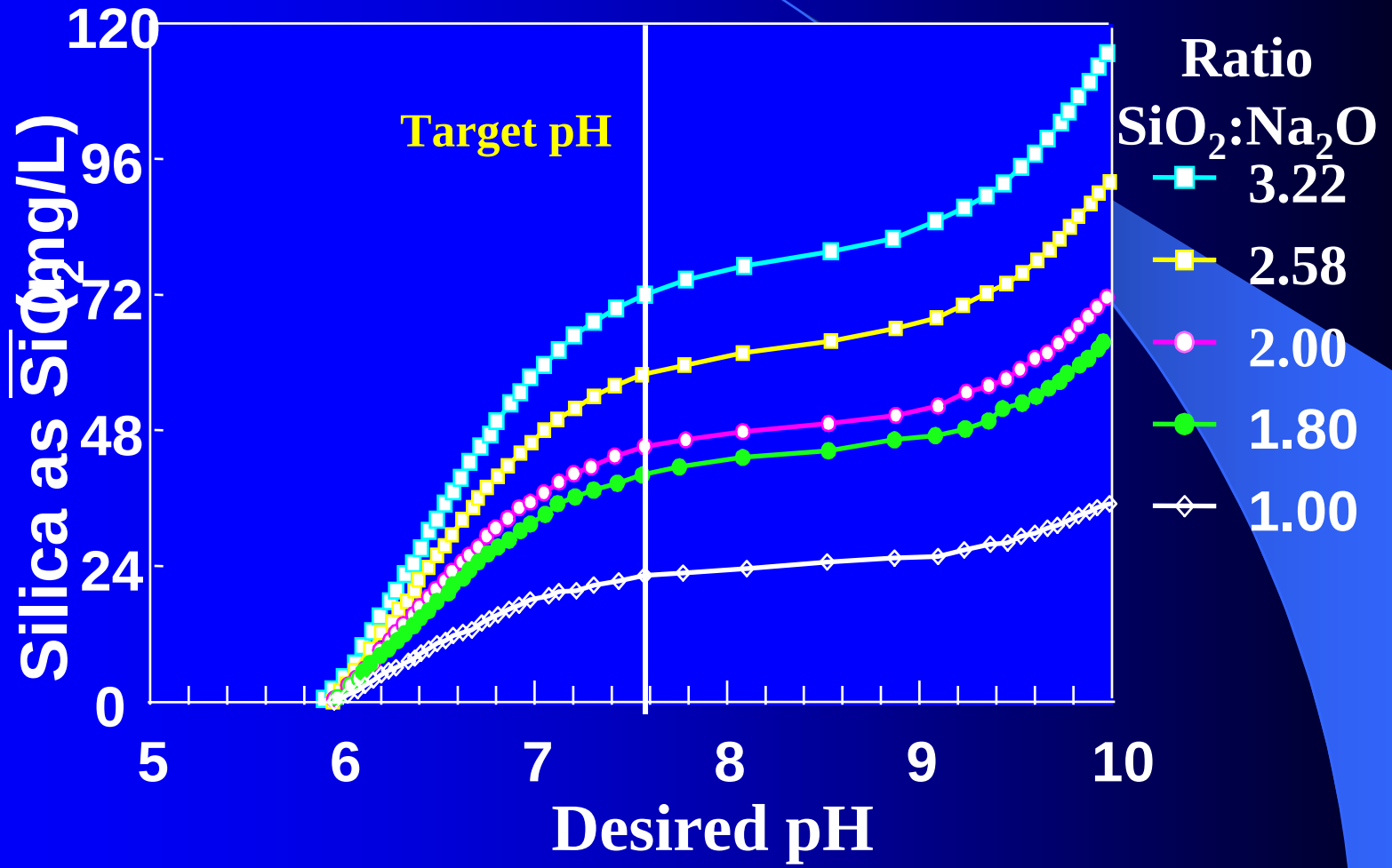
- Pre-1990: "Red water" complaints
- 1990: Polyphosphate feed, ~2 mg/L (as product)
- Flushing program to prevent/remove Fe
- Oct. 1992, LCR Monitoring
  - 0.077 mg Pb/L 90th percentile
  - 5.87 mg Cu/L 90th percentile

Approximate Water Chemistry Characteristics

	Wells 1-3	Wells 4-5
pH	6.1-6.3	6.0-6.3
Alk ($CaCO_3$)	25-30	20-25
TIC (mgC/L)	13-18	13-15
Ca	8	6
Fe	<0.01	0.3-3+
Mn	<0.01-0.2	0.2
SiO_2	10-14	10-12

pH Effect of Different SiO_2:Na_2O

Ratios at DIC = 13 mg C/L

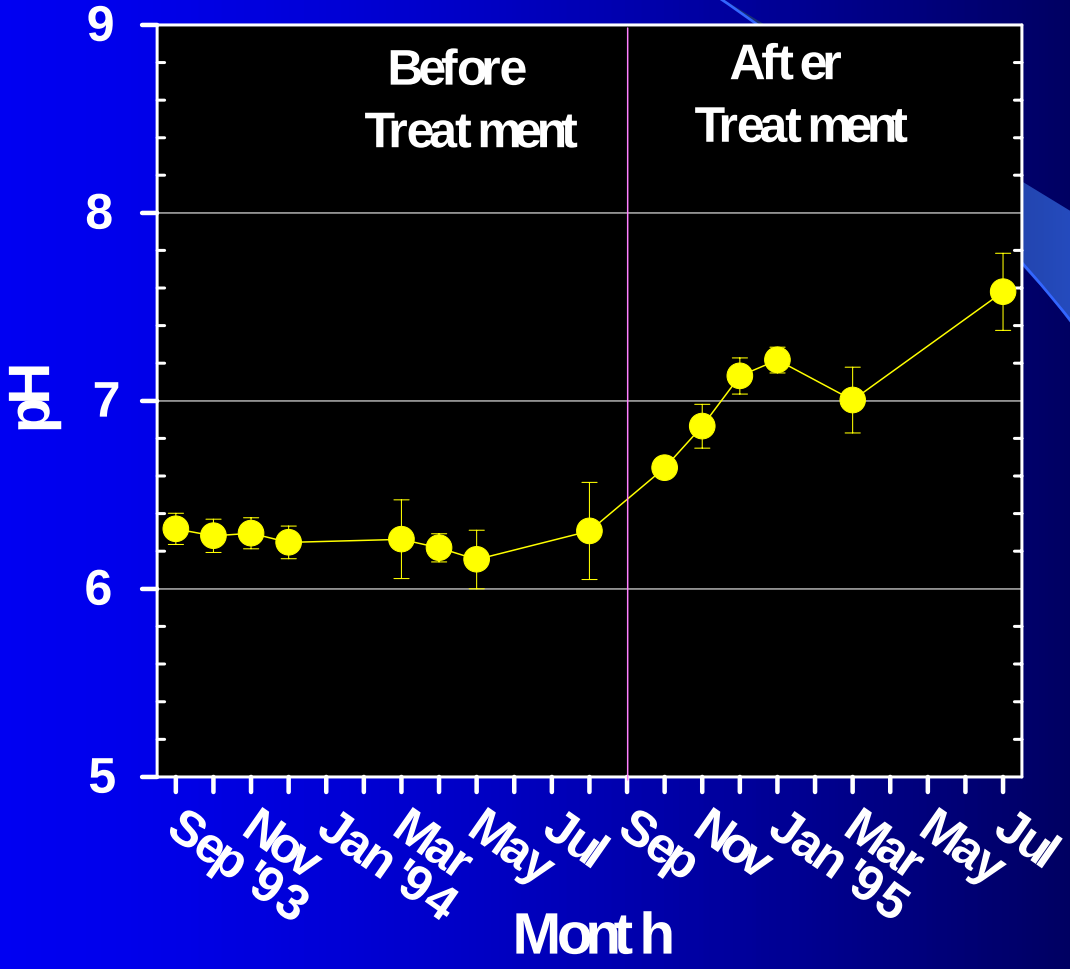


Silicate Feed System

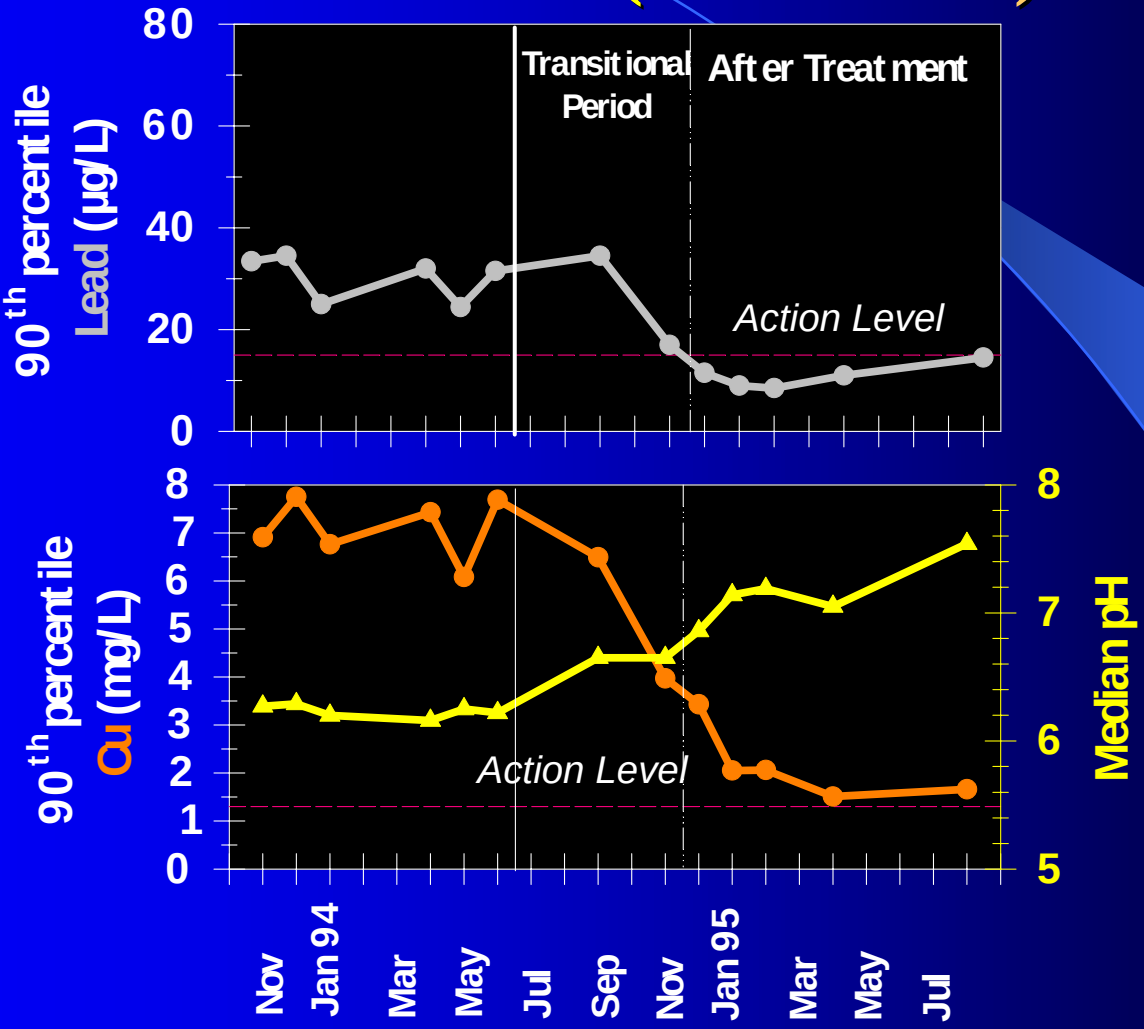
Treatment Change Observations

- Took several months for pH to stabilize in distribution system
  - Silicate “demand”?
  - pH Buffering of existing carbonate/phosphate/hydroxide scales?
- After 6 mos., silicate raised to match pH target better

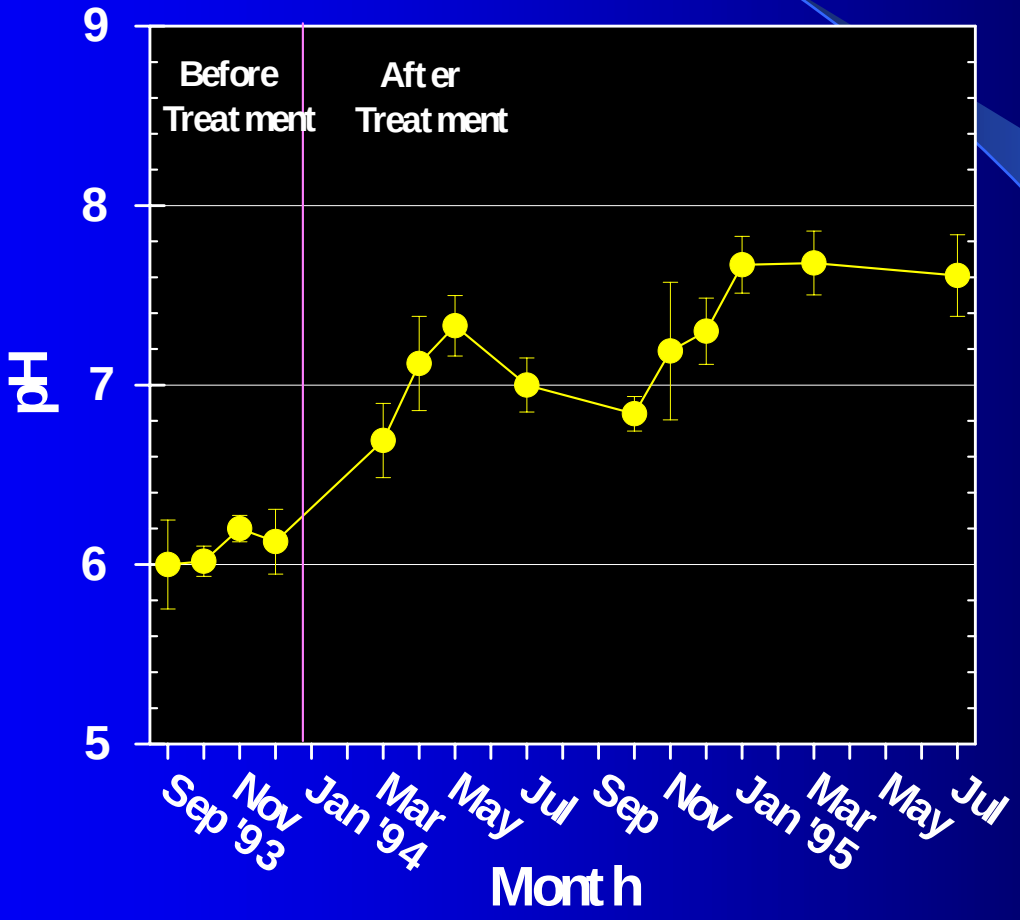
pH Effects, Wells 1 & 2



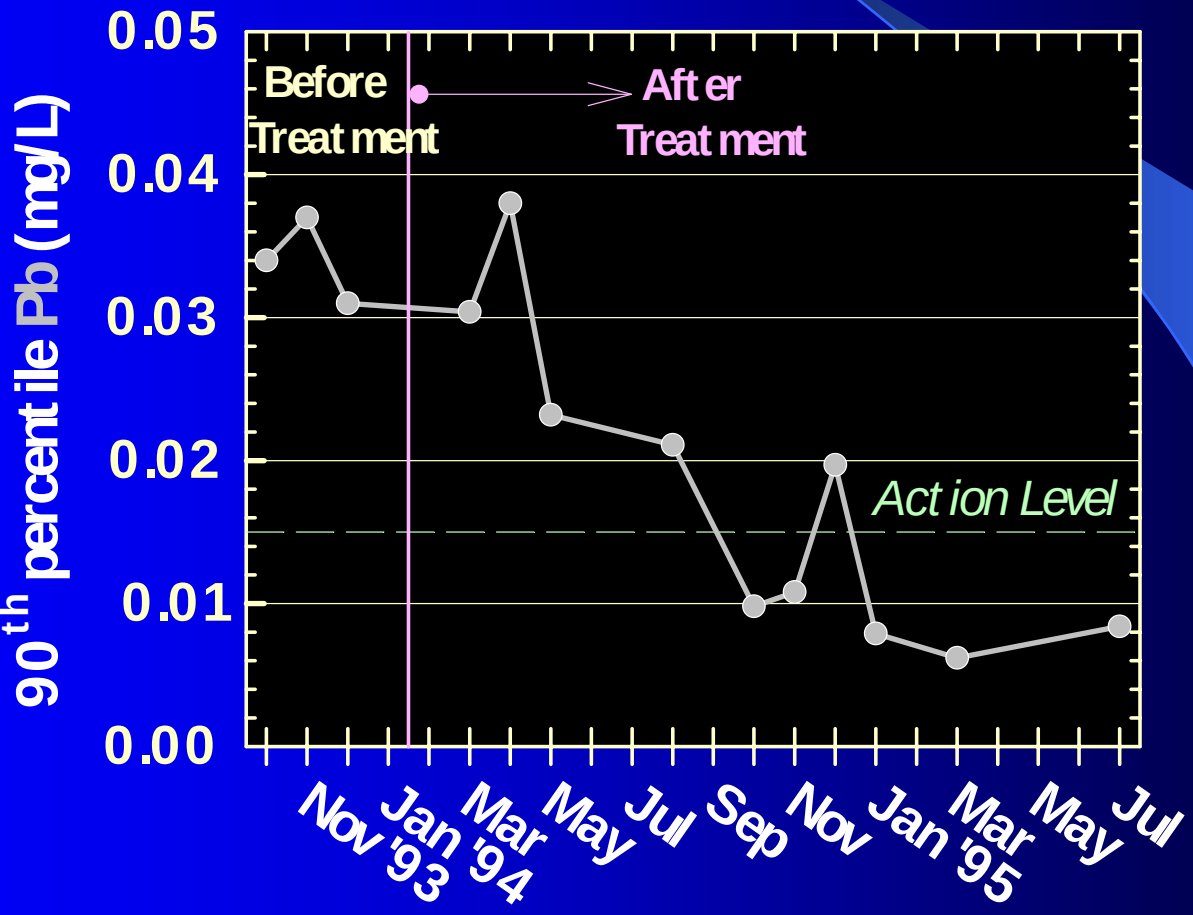
Corrosion Control in Section NaOH + Silicate (Wells 1 & 2)



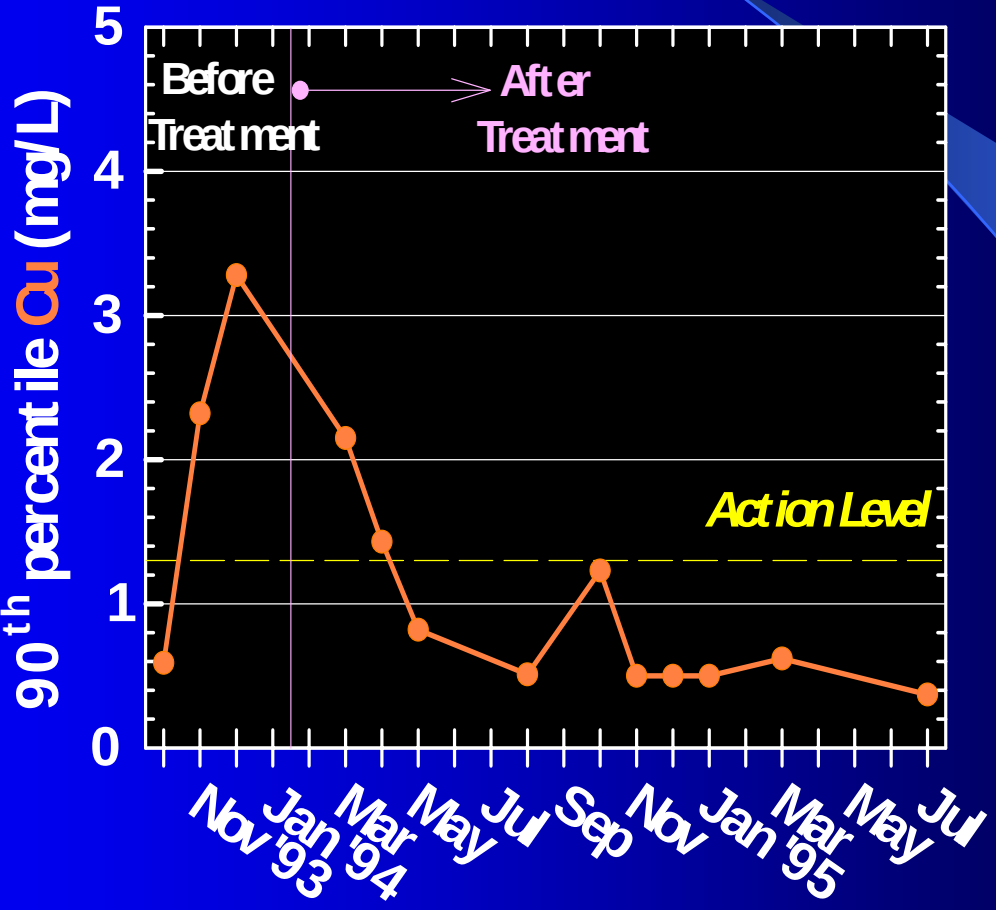
pH Effects, Wells 4 & 5



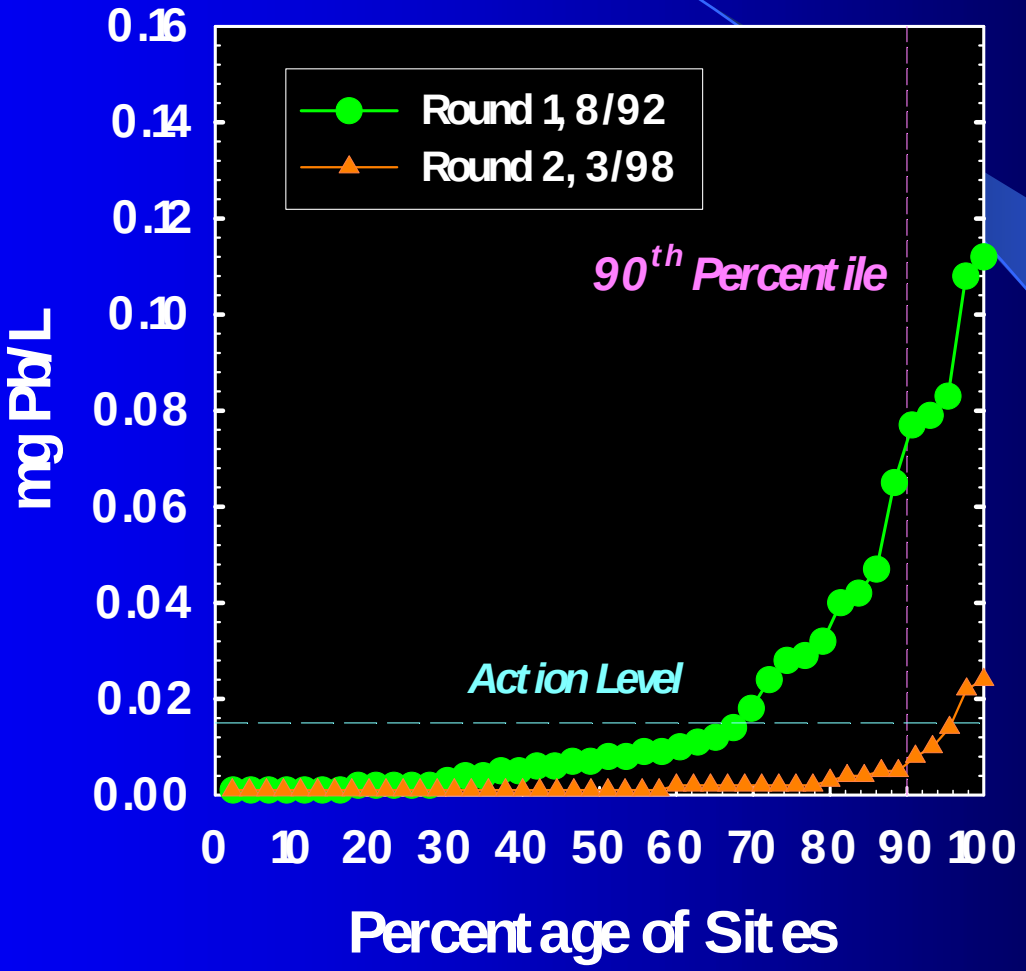
Corrosion Control in Section with Silicate (Wells 4 & 5)



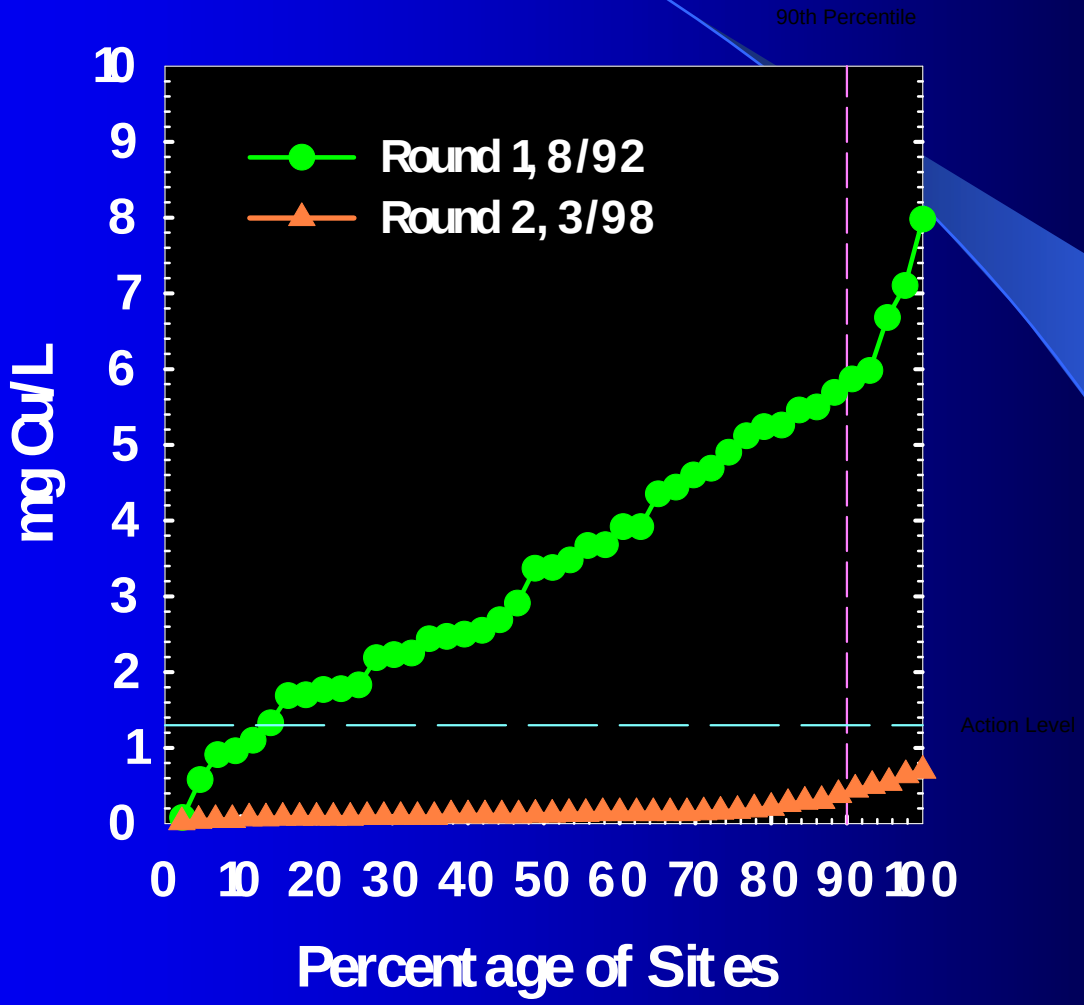
Corrosion Control in Section with Silicate (Wells 4 & 5)



Treatment Effectiveness: Pb



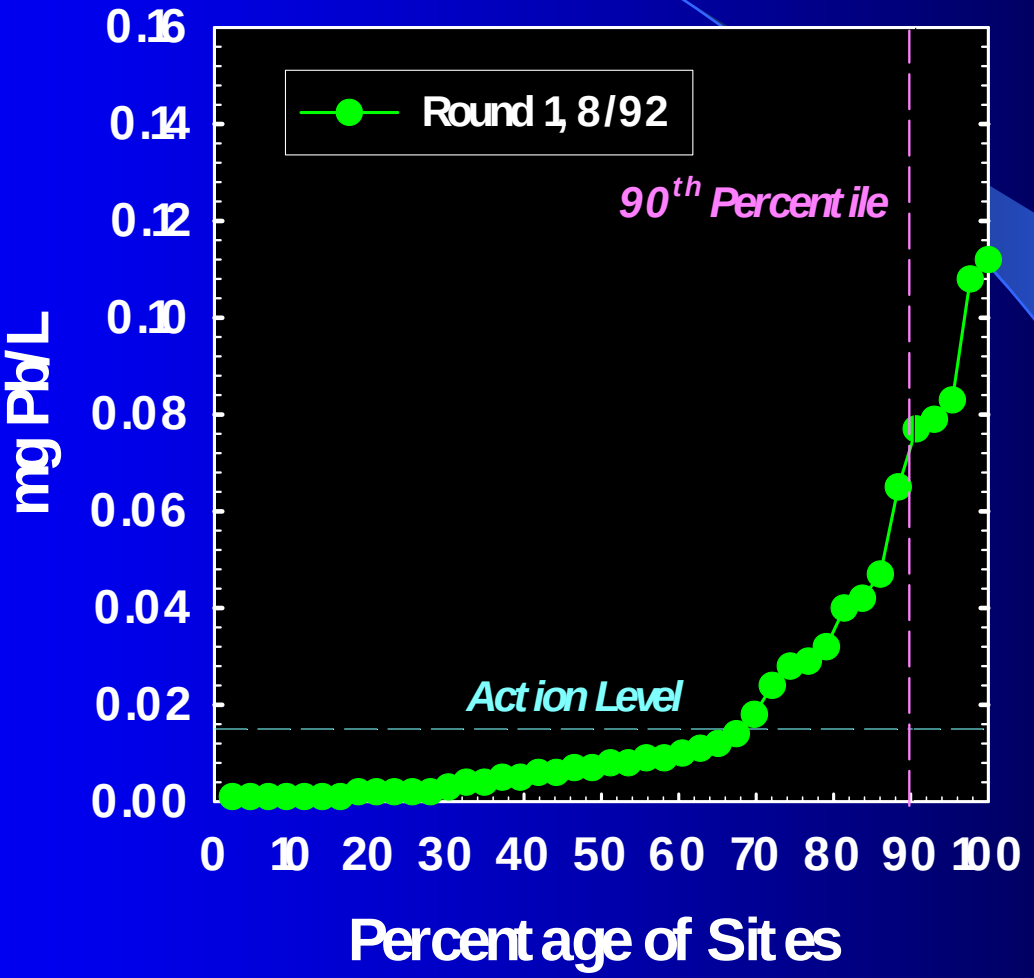
Treatment Effectiveness: Cu



Conclusion

- Silicates can be used to reduce lead and copper
  - Film
  - pH
- Secondary benefit of red water control
- Relatively simple to use

Initial Monitoring Results: Pb



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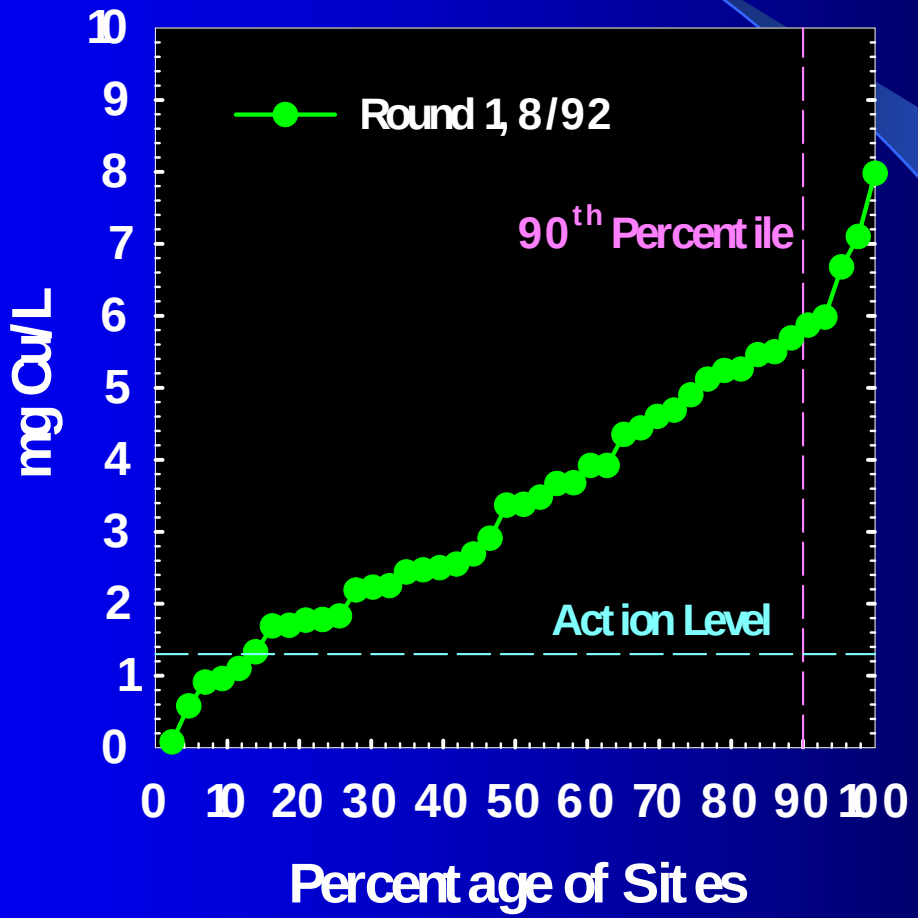
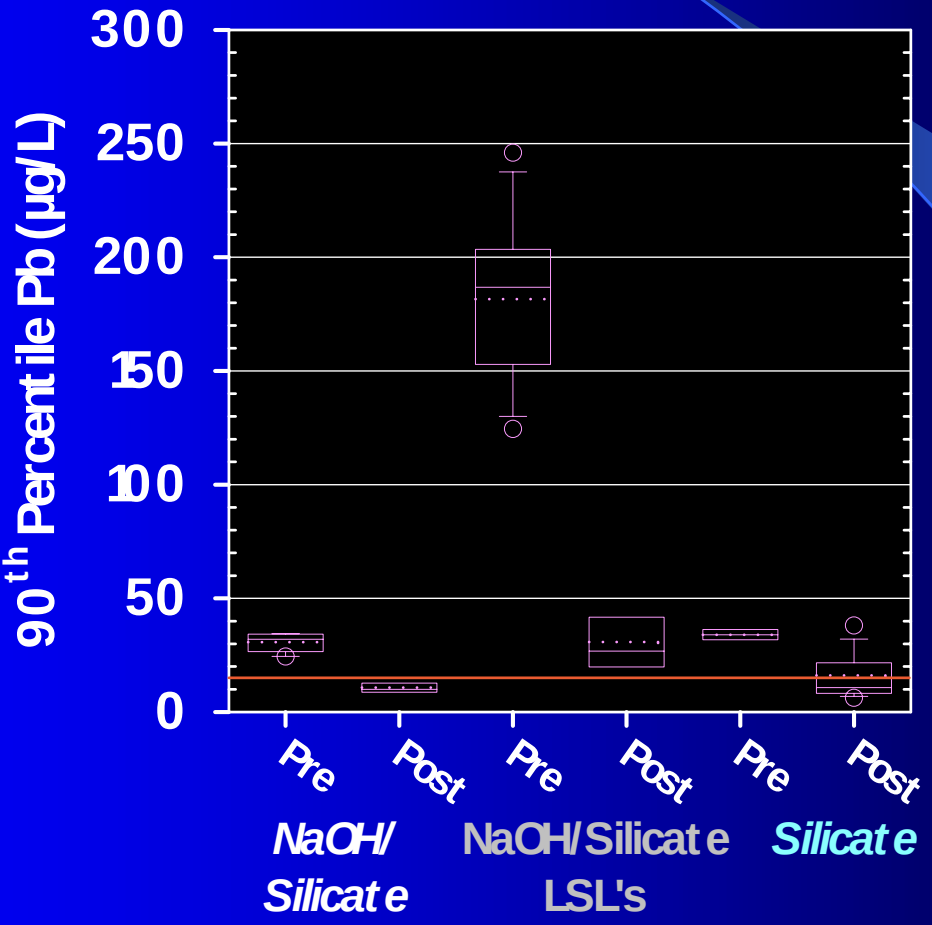


Treatment Effects on Pb Relating to Sites



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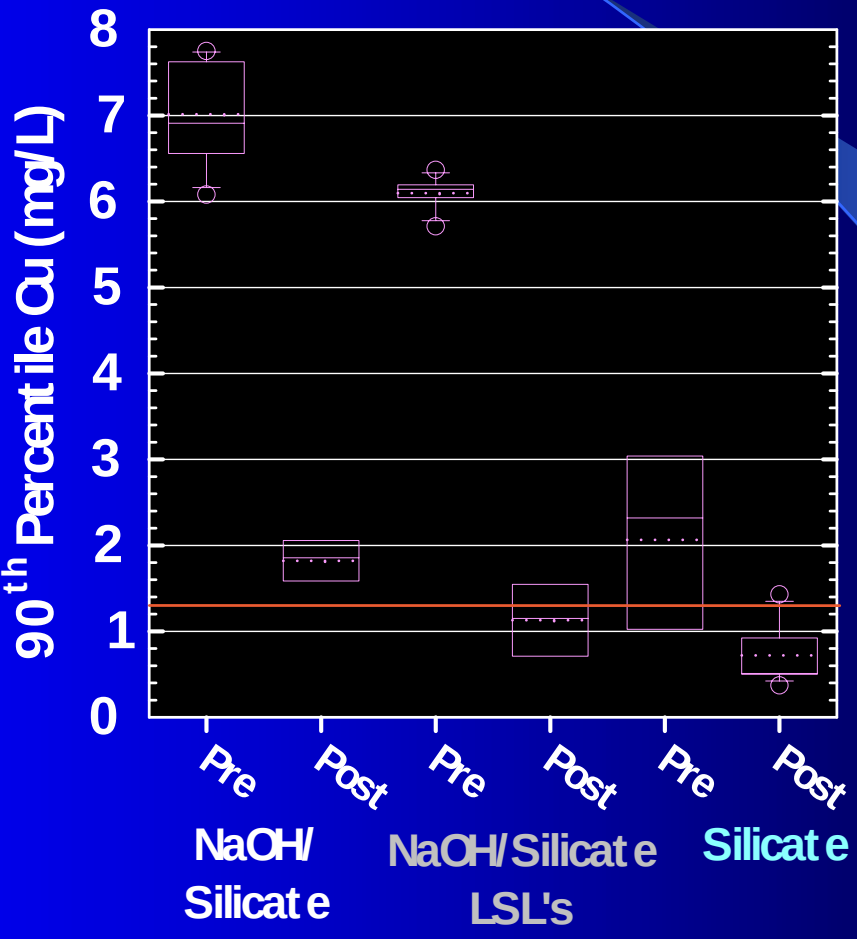
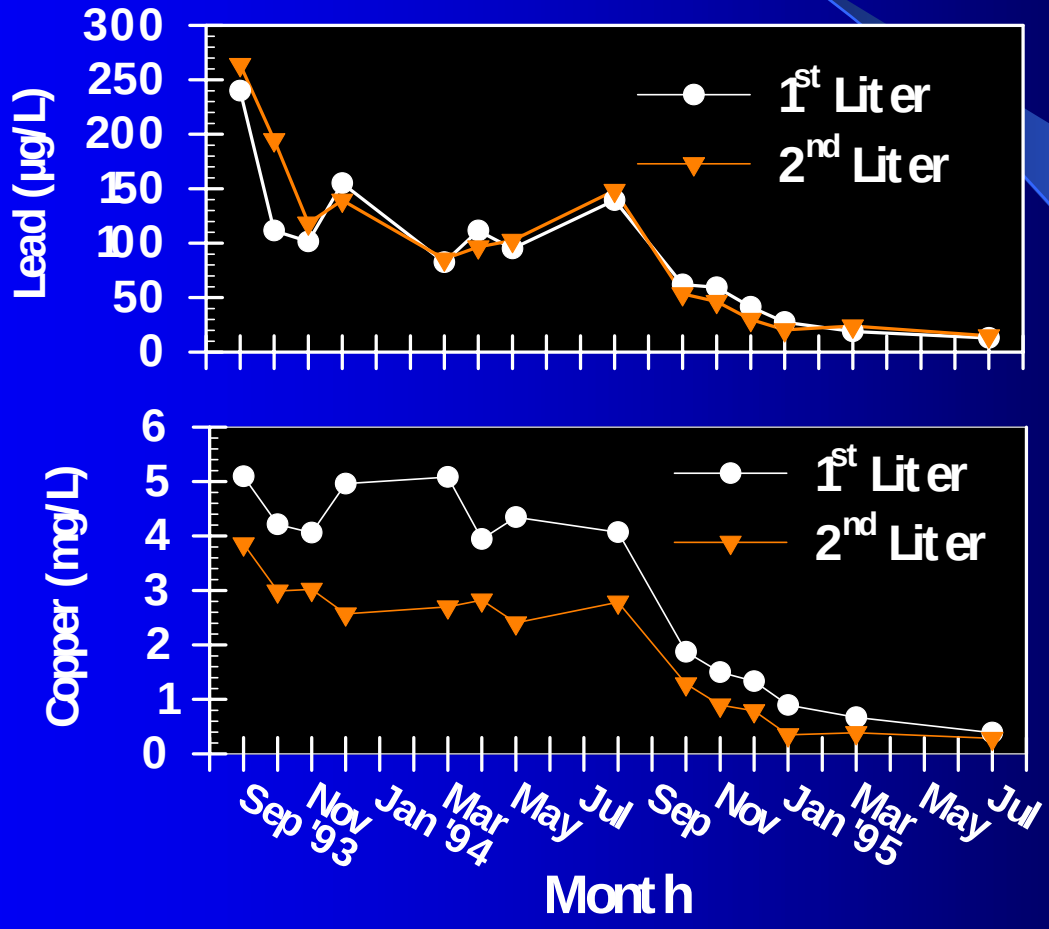
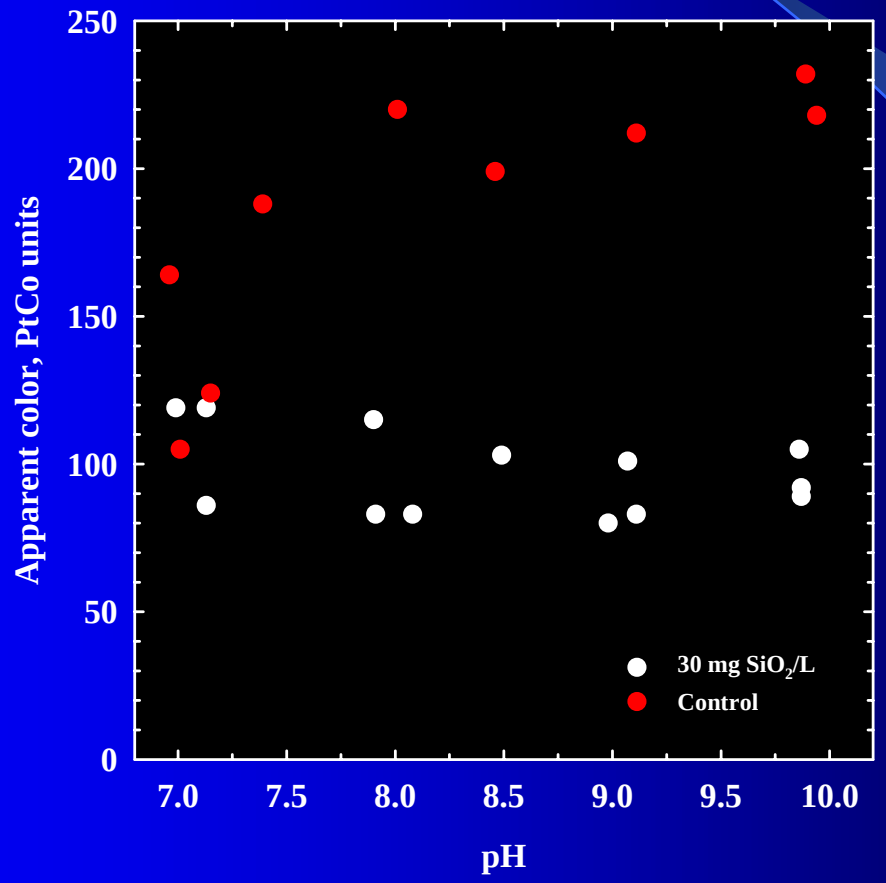


Sites with Lead Service Lines



Effect of Silicates on Iron Particles

DIC=5 mg C/L, 5 mg Fe/L, 30 mg SiO_2/L, 22°C



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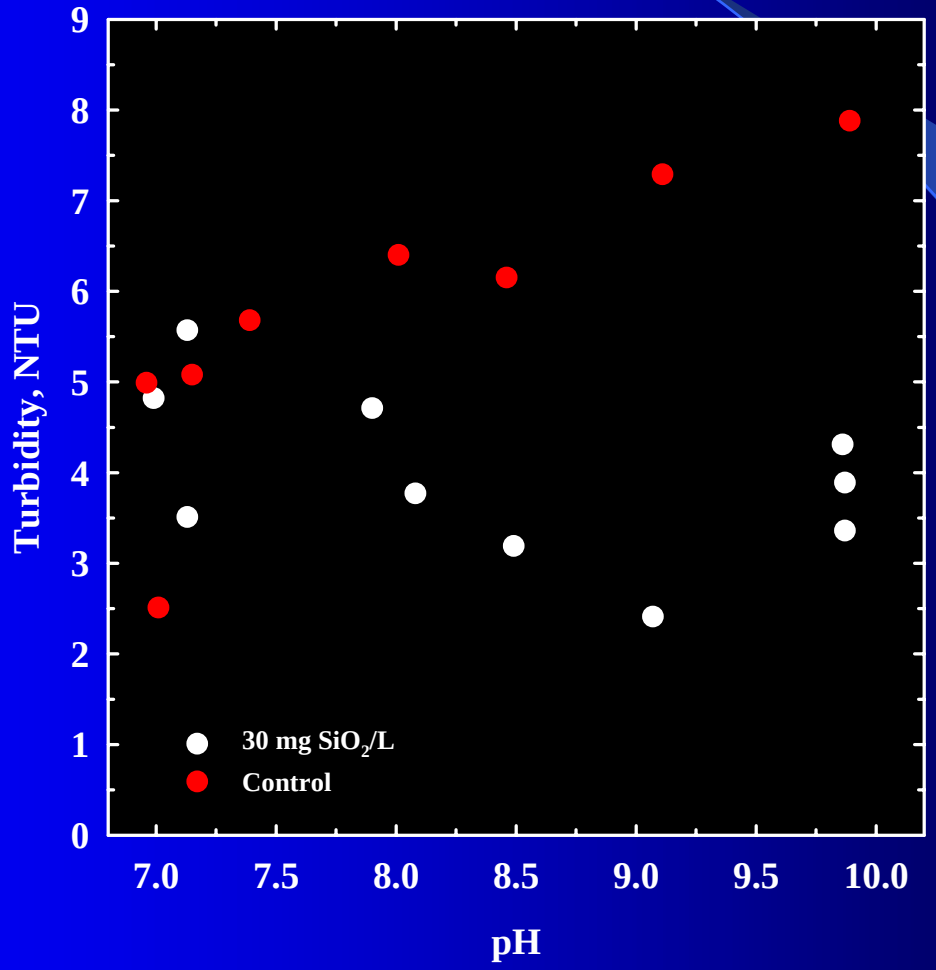
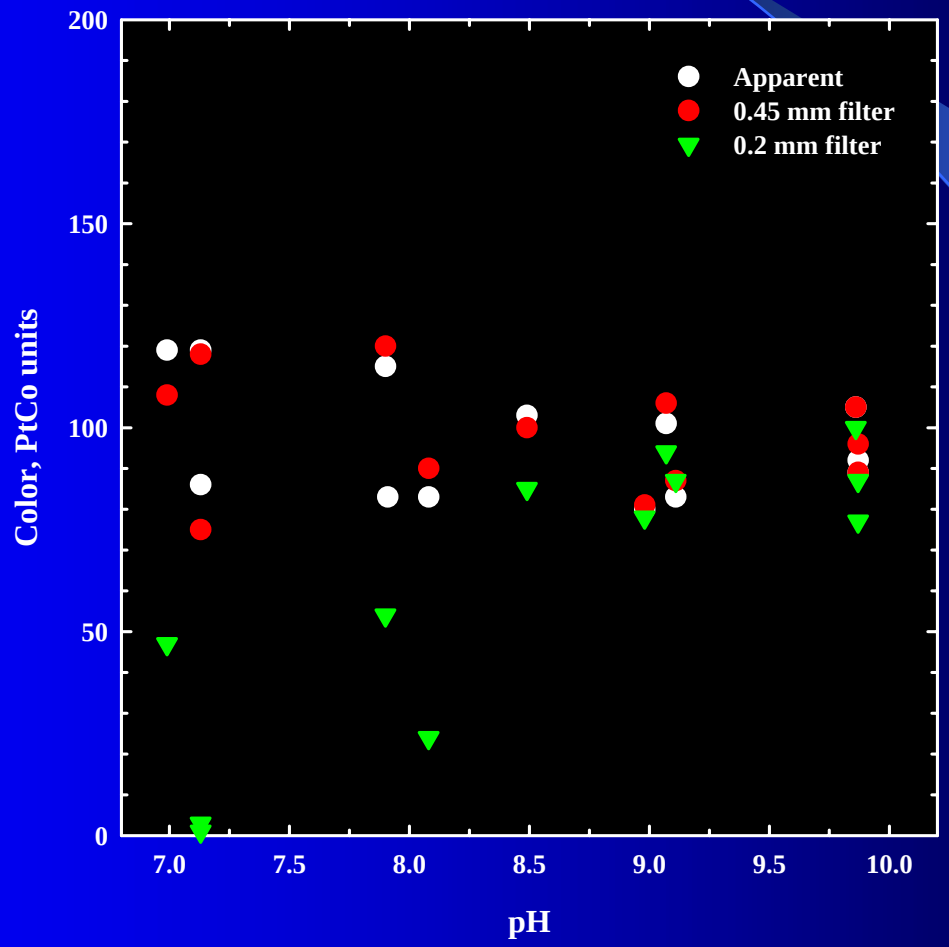
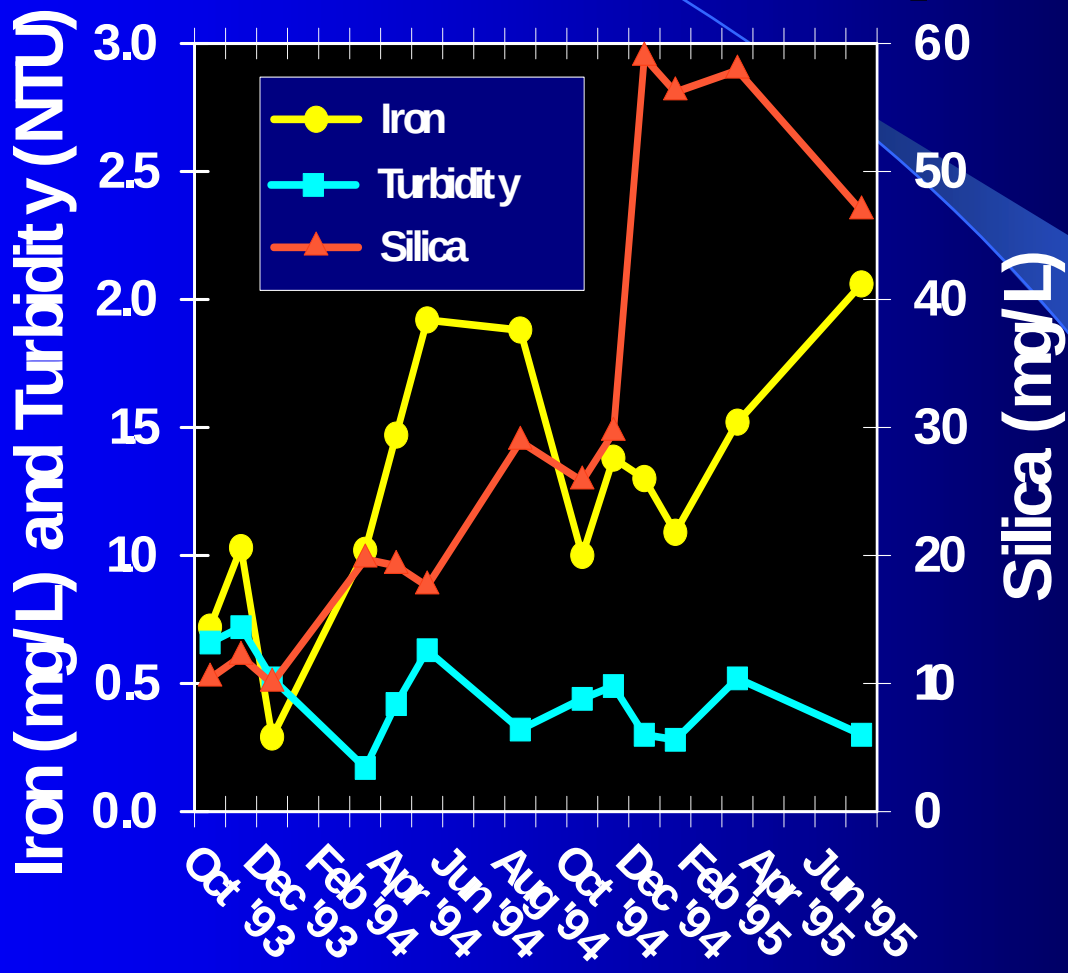



Apparent
0.45 mm filter
0.2 mm filter
Color, PtCo units
pH
200
150
100
50
0
7.0
7.5
8.0
8.5
9.0
9.5
10.0

Evidence of Effective Iron Sequestration



Sequestration Performance

- Color <15 cu, turbidity < 1.0 NTU at good pH for Pb and Cu control
- No clear relation of color and Mn, so adequate for this purpose
- Monthly hot water samples at 4 sites
  - higher color
  - lower iron
  - no clear sequestration breakdown

Operational Problems

- ☹ Clogging of silicate feed during first cold months
  - 1.6 ratio more viscous than 3.22 ratio product
  - higher amounts of solids
  - could congeal at 12ºC
- ☺ Solution:
  - maintain building above 15ºC
  - mfgr. improved process, reduced solids

Operational Problems

- ☹ Loss of suction on silicate feed pump
- ☺ Solution:
  - redesign solution tank to place bottom level above pump
  - transfer of silicate solution (barrels) by pump